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POSSIBILITIES FOR PORK FAT, PHOSPHATE AND NITRITE REPLACEMENT IN CHICKEN FRANKFURTER PRODUCTION

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A b s t r a c t: With the aim the possibility of total pork fat, phosphate and nitrite substitution in chicken frankfurters production to be examined, three variants of frankfurters made of chicken thighs, breasts and additives were produced: control – with pork fat, phosphate and nitrite (FPN); with vegetable oils and cochineal (OC); with vegetable oils, cochineal and paprika extract (OCP). Following parameters were investigated in all treatments of frankfurters: pH value, weight loss during heat treatment, proximate composition, phosphate content, residual nitrite content and degree of oxidation. The highest cooking loss (7.33%), during thermal processsing of frankfurters was established in variant FPN and the lowest one (6.68%) in OC. pH also was the highest (6.44) in FPN and the lowest (6.34) in OC. Moisture content ranged from 61.09% (OC), to 61.74% (FPN). Proteins were presented from 11.08% (OCP) to 11.92% (FPN), total crude lipids from 20.09% (OCP) to 22.11% (FPN), and ash from 2.73% (OCP) to 3.06% (OC). Phosphate content was reduced from 260.43 mg/100 g in control variant to 179.30 mg/100 g in OCP, or 157.30 mg/100 g in OC. Only in control variant residual nitrite (2.17 ppm) were determined, in which the initial input of nitrite was 55 ppm. Low TBA values (<0.20) indicate that lipid oxidation was almost completely prevented during the period of 42 investigated days. It can be concluded that pork fat substitution with rapeseed and sunflower oil; phosphate with combination of potato starch, caseinate and sodium citrate, and nitrite with cochineal and paprika extract in chicken frankfurters production is possible.

Key words: chicken frankfurters; pork fat; phosphate; nitrite; substitution

МОЖНОСТИ ЗА ЗАМЕНА НА СЛАНИНАТА, ФОСФАТИТЕ И НИТРИТИТЕ ВО ПРОИЗВОДСТВОТО НА ПИЛЕШКИ ВИРШЛИ

А п с т р а к т: Со цел да се испита можноста за целосна замена на сланината, фосфатите и нитритите при производството на пилешки виршли, беа произведени три варијанти виршли: контролна – со употреба на свинско масно ткиво, нитрити и фосфати (FPN); со растителни масла и кошенил (OC) и со растителни масла, кошенил и екстракт од пиперка (OCP). На готовиот производ се одредувани: pH-вредност, загуба во маса при термичкта обработка, хемиски состав, содржина на фосфати, содржина на резидуални нитрити и степен на оксидација. Највисока загуба во тежина во текот на термичката обработка на виршлите е утврдена кај варијантата FPN (7,33%), а најниска кај OC (6,68%). Вредноста на pH е исто така највисока кај FPN (6.44), а најниска кај OC (6,34). Содржината на вода се движи од 61,09% (OC) до 61,74% (FNP). Протеините се застапени од 11,08% (OCP) до 11,92% (FPN), мастите од 20.09% (OCP) до 22,11% (FPN) и пепелот од 2,73% (OCP) до 3,.06% (OC). Содржината на фосфати кај контролната варијанта е редуцирана од 260,43 mg/100 g на 179,30 mg/100 g кај OCP, односно на 157,30 mg/100 g кај OC. Резидуални нитрити се утврдени само кај контролната варијанта (2,17 ppm), во која иницијалниот импут на нитрити изнесуваше 55 ppm. Ниските ТБК вредности (<0,20) укажуваат дека оксидацијата на липидите е речиси целосно спречена за време на испитуваниот период од 42 дена. Може да се констатира дека при производството на пилешки виршли е можна замена на свинската маст со сончогледово и репкино масло; на фосфатите со комбинација на компиров скроб, казеинат и натриумов цитрат и на нитритите со кошенил и екстракт од пиперка.

Клучни зборови: пилешки виршли; сланина; нитрити; фосфати; замена

INTRODUCTION

Nowadays, obesity and cardiovascular disease are changing eating habits. These changes have fostered the development of products with functional ingredients that meet the market demands for maintaining a healthy body (Jiménez-Colmenero et al., 2010). Therefore, in recent years, these trends in health and lifestyle have been focused on reducing the consumption of animal fats (Ritzoulis et al., 2010) and replacing with vegetable oils which have positive effects on the cardiovascular system (Özvural and Vural, 2008).

Growing consumer demand for safe and healthy food products impose new criteria on the meat industry. It involves replacing chemical additives with natural alternatives and designing new meat products by modifying existing traditional recipes.

Phosphates are widely used as food additives as they contribute to the processing properties and functional characteristics of meat and poultry products. They are used in meat products to retain water holding capacity, inhibit lipid oxidation, reduce cooking loss, maintain color, and improve freeze-thaw stability **(**Long et al., 2011; Sebranek, 2015). Phosphates can improve the ability of water retention and textural properties of meat products (Long et al., 2011; Sebranek, 2015; Xiong, 2005).

The use of phosphate preparations (especialy some phosphate compounds such as tripolyphosphates, pyrophosphates, hexametaphosphates) as well as some polyphosphate mixtures (for which animal experiments have been performed) may cause cytotoxic and other adverse health effects (Modić, 2001).

Efforts have being made to find natural phosphate alternatives, due to reports suggesting that excessive consumption of synthetic phosphate in processed foods could inhibit calcium absorption and bone formation (Kemil et al., 2006).

Nitrites and nitrates are two important additives in the meat industry due to their beneficial effect on the quality and microbiological safety of meat products (Govari and Pexara, 2015). The pink color and cured taste of frankfurters are due to the reaction of nitrite with myoglobin (Pegg and Shahidi, 2000). Nitrite also acts as an antioxidant and inhibits the growth of *Clostridium botulinum* (USDA-FSIS, 1995). Nitrates and nitrites have been used to achieve and preserve the color of the product, and, in combination with other factors, they would reduce or prevent the growth and reproduction of bacteria that spoil food and the development of pathogenic microorganisms (Weber, 2004; Sindelar and Milkowski, 2011; Kovačević at al., 2016; Ha et al., 2016; Lee et al., 2018).

When processing meat or meat products, there is a reaction between added nitrites and meat proteins. Harmful carcinogenic compounds N-nitrosamines are produced as a product of the nitrosation reaction (Rywotycki, 2001; Bošnir et al., 2003). Studies show that nitrites can be potentially carcinogenic if added to high-protein foods that are subsequently treated at high temperatures. Therefore, the addition of nitrites and nitrates in food is associated with carcinogenicity (Pegg and Shahidi, 2000; Honikel, 2008; Bouvard et al., 2015). Nitrites can cause the destruction of red blood cells (erythrocytes), and they can also react with amines to produce mutagenic, teratogenic and carcinogenic substances. Animal experiments have shown that nitrites can cause certain changes in cytogenetic parameters, i.e. can lead to chromosomal aberrations and exchange of sister chromatids so that according to some cytogenetics nitrites are classified as genotoxic agents in food (Modić, 2001).

Meat and meat product consumption is gradually being seen as causes for increased risks of attracting chronic diseases such as obesity, cancer and stroke. While this view often neglects that meat is also an essential factor in maintaining human health, it nevertheless forces the meat and meat product industry to react (Weiss et al., 2010).

During the last few decades, the consumption of poultry meat has tremendously increased (Anonymous, 2011). The main reasons for the success of poultry meat production are: the healthy and nutritional image of poultry products; their suitability for processing which enables the meat producers to launch more attractive, convenient, easy to use products; lower price compared to red meats; absence of cultural or religious effect (Cavani et. al., 2009).

Frankfurters are emulsion type cooked sausages, which are very popular and highly consumed meat product in many countries (Özvural and Vural, 2008). Frankfurters prepared with chicken have a healthy image because of the low-fat content (18–22%) compared to frankfurters prepared with red meat (25–30% fat) (USDA, 2009).

Starches are the most widely used carbohydrates which can serve as fat replacer and contribute to the firm texture of the product (Keeton, 2001). Potato and tapioca starches are the most widely used in poultry meat products. Potato starch has some privileges like low gelatinization temperature (60–65ºC), high water binding capacity and high viscosity which make it favourable for meat industry (Petracci et al., 2013).

Sodium caseinate is used to improve moisture retention, fat binding and textural characteristics of cooked meats (Xiong, 2009). Addition of biopolymers prepared with soybean proteins, caseins, whey protein isolate in the manufacture of chicken sausages could be used to reduce phosphate content without impairing the texture (Muguruma et al., 2003).

Citrates are widely used in poultry meat product formulation to improve water binding capacity by increasing the ionic strength and swelling of muscle fibre structure. Alkaline citrates (e.g. trisodium citrate) are the most common salts used in meat industry to improve water holding capacity by raising the pH value (Feiner, 2006).

Cochineal is the red color, which is obtained from an insect (*Dactilopious coccus*), and paprika (E160c) is an orange pigment extracted from sweet red peppers, *Capsicum annum* L., to maximize the color while minimizing the flavor that is concentrated **(**Delgado-Vargas and Paredes-López, 2002; Kendrick, 2012; Kendrick, 2016). Both colors could be used to mimic the cured-meat color (Eskandari et al., 2013). Because the colorful carotenoids in paprika extracts are also powerful antioxidants, the addition of paprika or pepper powders is also used to enhance the oxidative stability of lipids and proteins in meat patties (Duthie et al., 2013).

The intention to reduce the risks of various diseases when consuming chicken sausages resulted in the motivation for this research, which aimed to try to replace pork fat, phosphates and nitrites in chicken frankfurters with rapeseed and sunflower oil; potato starch, caseinate and sodium citrate; cochineal and paprika extract.

MATERIAL AND METHODS

Frankfurters made from chicken (boneless breast and thigh) were used in the present investigation. A cocktail of vegetable oils (rapeseed and sunflower oil) was used to replace pork fat in the production of frankfurters. As an alternative to phosphates, potato starch, caseinate, sodium citrate and a higher percentage of meat were used. Cochineal and paprika extract were used as an alternative to nitrites. Three frankfurter formulations were produced, compositions of which are shown in Table 1. The control frankfurters were prepared with pork fat, phosphate and nitrite (FPN). The other two types of frankfurters were prepared with vegetable oils and cochineal (OC), and with vegetable oils, cochineal and paprika extract (OCP).

Table 1

Frankfurter formulation (%)

Ingredients	FPN	OC	OCP
Chicken breasts without skin	21	25	25
Chicken thighs without skin	21	25	25
Pork fatback	25		
Sunflower oil		8	8
Rapeseed oil		12	12
Ice	31	28	28
Potato starch		2	2
Na-citrate		0.02	0.02
Soy protein isolate	2		
Na-lactate	2	2	2
Nitrite curing salt	1.1		
NaCl		1.1	1.1
Phosphate	0.2		
Vitamin C	0.05	0.05	0.05
Caseinate		1	1
Mixture of spices	0.2	0.2	0.2
Cochineal		0.003	0.003
Paprika extract			0.03

Artificial collagen edible casings, 23 mm in diameter (Naturin GmbH, Weinheim, Germany), were used for stuffing the batter. Heat treatment was performed in smokehouse at 78˚C until an internal temperature of 72˚C was achieved.

Value of pH was measured in aqueous extract by pH meter Sartorius PB-20.

Weight loss during thermal processing of the frankfurters was calculated from the difference in weight before and after heat treatment, expressed as a percentage of weight before thermal processing of the frankfurters.

Chemical composition was determined according to standard methods (AOAC, 2005). The water content was determined by drying the meat in an oven at 105˚C according to official method AOAC 950.46. Total proteins (Nx6.25) were determined using the Kjeldahl method according to AOAC 928.08. Crude fat content was measured according to AOAC 991.36 and ash content according to AOAC 920.153.

Phosphate content was determined based on annealing of the sample at 650˚C, hydrolysis with HNO_3 and spectrophotometric determination of the total phosphate.

Residual nitrite concentration was determined using the method of Greau and Mirna (Rajar et al., 2003).

The degree of lipid oxidation in frankfurters was determined by the TBARS (Thibarbituric Acid Reactive Substances) test according to the method of Tarladgis et al. (1960) modified by Shahidi et al. (1987). The determination was performed 42 days after the production. Until then, vacuum-packed sausages were stored in a refrigerator at a temperature of 0–2˚C.

The program package SAS/STAT (1999) was used for statistical processing of data according to GLM (General Linear Model) procedure, means were separated using Duncan's test.

RESULTS AND DISCUSSION

To get healthy food, the best solution is to get rid of the addition of additives that are harmful to health. Replacing harmful additives is not easy at all, because there are problems of technological, sensory and health nature. Replacement of pork fat, phosphates and nitrites is done with the intention of producing "healthy" food. Natural components are used to obtain a system that will be safe for human health.

In present research, by replacing pork backfat with sunflower and rapeseed oil, an attempt was made to obtain a product with a better nutritional composition. A higher percentage of meat components was used to replace phosphates, because meat itself contains natural phosphate, as well as potato starch, caseinate and sodium citrate, which replace phosphates water-binding function. To avoid the formation of carcinogenic nitrosamines, nitrites were eliminated and paprika extract and cochineal were used as color additives.

Weight loss during heat treatment was the highest (7.33%) in frankfurters with the addition of phosphate and nitrite (FPN). The other formulation (OC and OCP) had lower weight loss, which is in line with the data obtained in the literature that the addition of starch and sodium citrate, as well as lower fat content, affect the reduction of weight loss in products (Table 2). Thus, Ruusunen et al. (2003) produced phosphate-free frankfurters with low NaCl content, in which the effects of salt, modified tapioca starch, sodium citrate, wheat bran and fat were examined. Modified tapioca starch and sodium citrate decreased frying loss, with the former also improving water and fat binding.

Weight loss during thermal processing is influenced by cooking method (Yoo et al., 2005), cooking temperature and time (Kim and Chin, 2007;

Table 2

Weight loss during thermal processing and pH of frankfurters

Parameters	Treatments								
	FPN			OC			OCP		
	$\overline{x}$	Sd	Cv	$\overline{x}$	Sd	Cv	$\overline{x}$	Sd	Cv
Weight loss (%)	7.33	0.60	8.18	6.68	0.19	2.84	7.04	1.06	15.05
pH before heat treatment	6.23	0.12	1.92	6.19	0.02	0.32	6.19	0.01	0.16
pH after heat treatment	6.44	0.02	0.31	6.34	0.008	0.12	6.35	0.01	0.15

$\overline{x}$ – mean value; Sd – -standard deviation; Cv –coefficient of variation

Vasanthi et al., 2007; Banon et al., 2008), the type and the amount of fat (Belichovska et al., 2016; Choi et al., 2010; Choi et al., 2009; Hong et al., 2004; Fernández-Ginés et al., 2004), ingredients (Huang et al., 2005), the casing (Choi et al., 2008).

The pH value of frankfurters before heat treatment was the highest in the FPN formulation (6.23), and the other two treatments had identical values (6.19). After thermal processing, the pH values were higher in all frankfurter formulations. The highest pH value after heat treatment had control frankfurters FPN (6.44), and the lowest, OC (6.34), which is in accordance with the studies of several authors (Table 2). Thus, according to Klettner (1993), the pH values of the frankfurters are usually in the range of 6.2 to 6.4. Belichovska et. al. (2016) reported similar results (6.36 – 6.38) for chicken frankfurters with vegetable oils. According to Paneras and Bloukas (1994) pH in frankfurters produced with vegetable oils is usually in the range of 6.30 to 6.46 and in those with pork fat is higher. Choi et al. (2009) found a slightly higher pH (6.46 to 6.47) in sausages formulated with vegetable oil and rice bran fiber.

The water content in the frankfurters ranged from 61.09 to 61.74%. The highest percentage of water contained the sausages with phosphate and nitrite addition. The representation of proteins ranged from 11.08 to 11.92%. The values for fat content were quite low and ranged from 20.09% in the OCP treatment to 22.11% in the FPN treatment. The presence of mineral substances ranged from 2.73 to 3.06% (Table 3). No major deviations between treatments in terms of chemical composition were identified.

The addition of cochineal and paprika, as nitrite alternatives, butylated hydroxyanisole as antioxidant, and sodium hypophosphite as antimicrobial agent had no effect on pH values and proximate analyses of frankfurters (Eskandari et al., 2013).

Table 3.

Chemical composition and phosphate content of frankfurters

Parameters	Treatments								
	FPN			OC			OCP		
	$\overline{x}$	Sd	Cv	$\overline{x}$	Sd	Cv	$\overline{x}$	Sd	Cv
Water (%)	61.74	0.09	0.14	61.09	0.02	0.03	61.25	0.25	0.40
Protein (%)	11.92	0.08	0.67	11.74	0.36	3.06	11.08	0.27	2.43
Fat (%)	22.11	0.21	0.94	21.60	1.19	5.50	20.09	2.14	10.64
Ash (%)	2.96	0.0004	0.01	3.06	0.14	4.57	2.73	0.008	0.29
Phosphate (mg/100 g)	260.43	183.40	70.42	157.30	47.15	29.97	179.30	82.75	46.15

$\overline{x}$ – mean value; Sd – standard deviation; Cv – coefficient of variation

The phosphate content was the highest in the control treatment of frankfurters (260.43 mg/100 g), because phosphates were added to this treatment (Table 3). The other frankfurter formulations had a lower phosphate content, which actually representted phosphates from the raw material itself (chicken breast and thigh).

Residual nitrites were detected only in the control treatment (FPN) to which nitrites were added at a concentration of 2.17 ppm. No residual nitrites were registered in other treatments. The initial nitrite input in this treatment was 55 ppm, which means that 3.94% of the initial nitrite was registered as residual. Residual nitrite concentration in a meat product is dependent on a number of factors including the thermal processing, the pH of the product, the addition of reducing agents, the temperature of storage, and the proximate composition of meat product (Honikel, 2008; Delgado-Pando et al., 2011). According to Cassens (1997), after the ending of production process, about 10–20% of the initially added nitrites can be detected.

Chicken meat contains relatively high amounts of unsaturated fatty acids, which increases the concerns regarding oxidative deterioration. This oxidation often determines the shelf life of pre-cooked, chilled and ready-to-eat products made from chicken meat (Xiao et al., 2011).

TBA numbers were measured only in the treatments in which no colour development accessories were used, because the use of colour gives invalid TBA numbers when measuring absorbance. TBA numbers, which are malonaldehyde content expressed in mg/kg product are shown in Table 4.

Table 4

TBA-test of frankfurters (mg/kg)

Treatment	Parameters				
	$\bar{x}$	Min	Max	Sd	Cv
FPN	0.074	0.024	0.170	0.04	54.05

$\bar{x}$ – mean value; Min – minimum value; Max – maximum value,;
Sd – standard deviation,
Cv – coefficient of variation.

TBA numbers, after six weeks of storage of vacuum-packed frankfurters, were very low (<0.20 mg/kg). This is due to the antioxidant effect of the nitrites themselves. These values indicate the fact that lipid oxidation was almost completely prevented.

Many undesired chemical reactions can take place among which lipid oxidation is the most unfavorable and can negatively affect the colour of the meat product. These chemical reactions inducing discoloration of meat products are dependent on various factors like ambient temperature, addition of antioxidants, applied smoke, haem pigment concentration and other (Rohlík et al., 2013).

An acceptable alternative to pork fat in the production of chicken frankfurters is the use of sunflower and rapeseed oil in combination. Phosphates can be replaced by using potato starch, caseinate, sodium citrate and a higher percentage of meat containing natural phosphate. Nitrite substitution is possible with the use of cochineal and a combination of cochineal and paprika extract.

The addition of natural replacers can be used for development of new functional frankfurters. Further experiments will be needed to optimize the design of new functional cooked sausages.

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